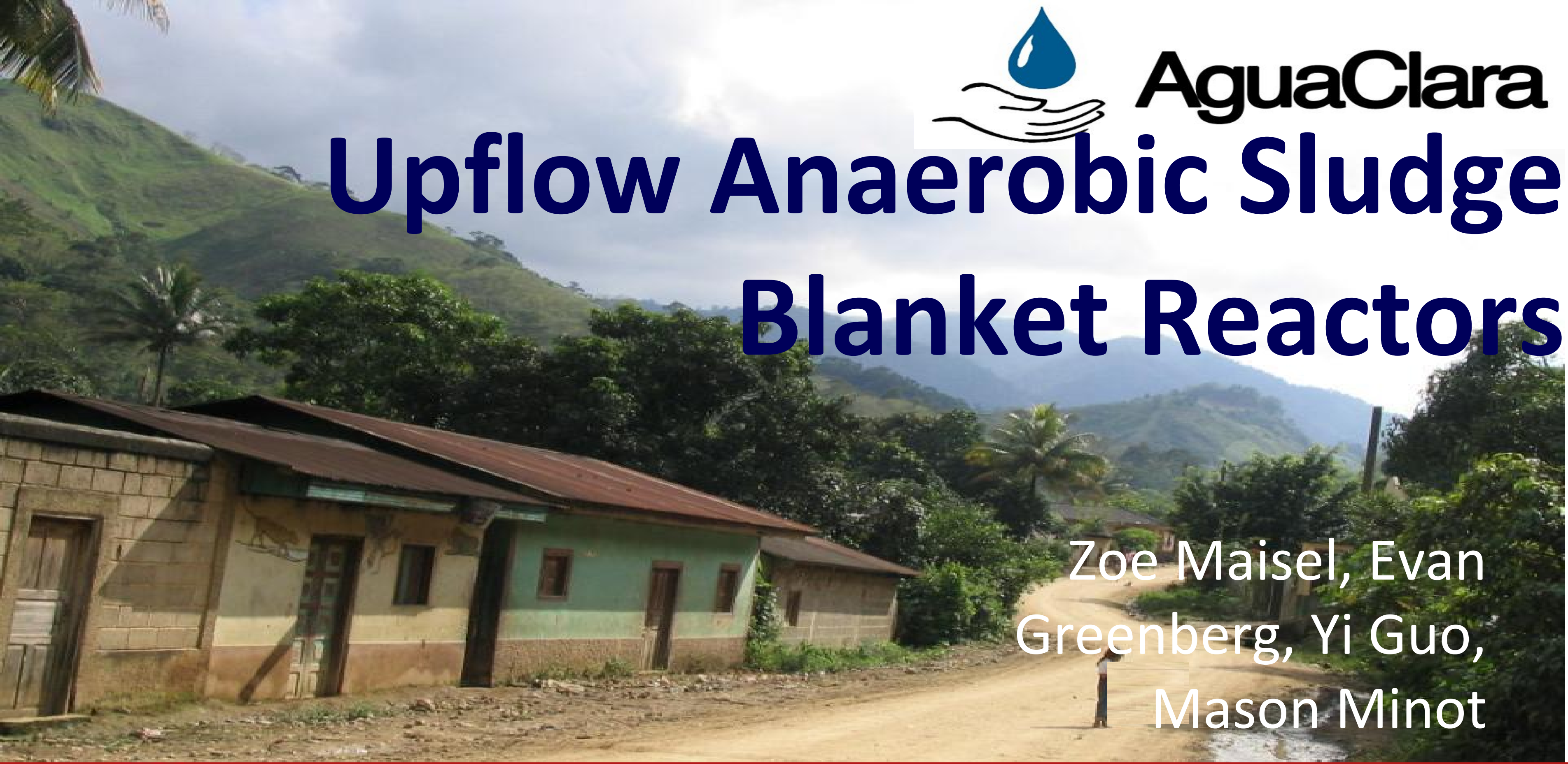

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Upflow Anaerobic Sludge Blanket Reactors

Zoe Maisel, Evan Greenberg, Yi Guo, Mason Minot

Cornell University

Wastewater Around the World

- "Up to 90% of wastewater in developing countries does not undergo treatment" [1]

- Environmental and health hazard

https://www.laprogressive.com/dumping-wastewater-into-aquifers/

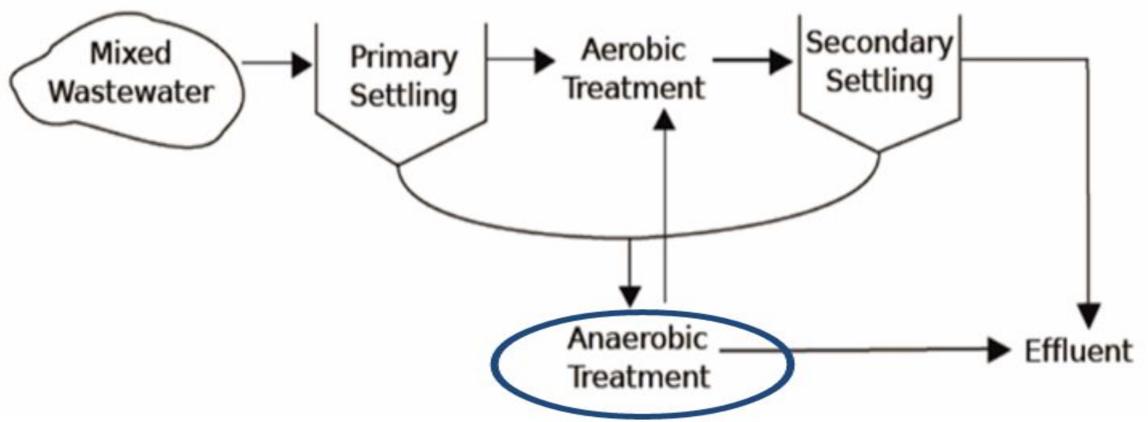
Current State of Treatment

- Large capital and operational costs
- Large energy demand
- Difficult to handle lower flows

Alternative Treatment Goals

- Low cost
- Energy neutral/positive
- Small scale treatment
  (households to small communities)
- Reduce biological sludge production

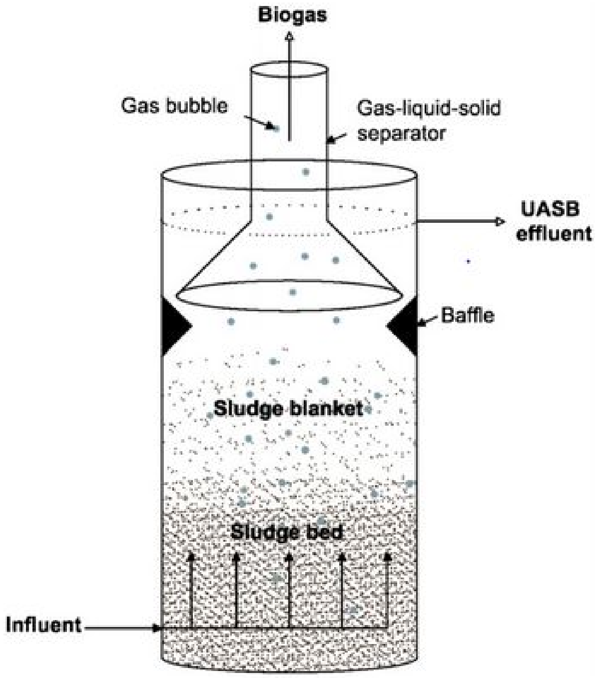
Proposed Treatment Process Flow



- Combining anaerobic and aerobic treatment can reduce the need for downstream processing

Upflow Anaerobic Sludge Blanket (UASB)

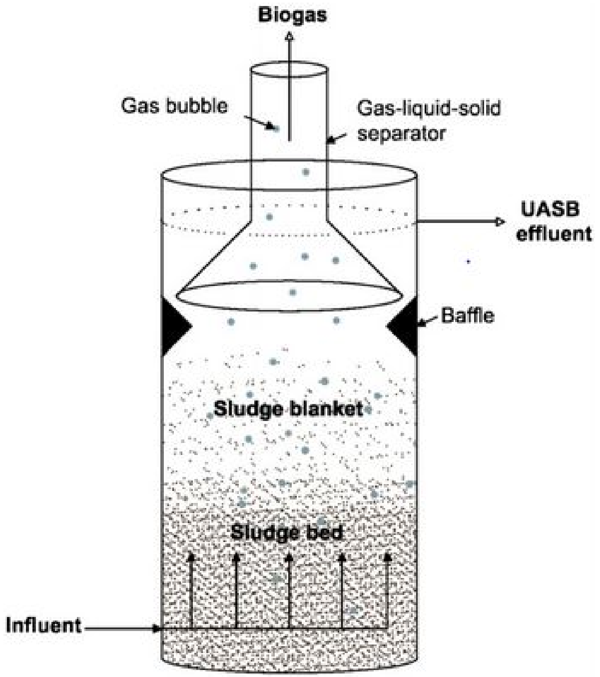
- influent wastewater contains chemical oxygen demand (COD)
- granular biomass of a mixture of bacterial species form a sludge bed and fluidized sludge blanket



Upflow Anaerobic Sludge Blanket (UASB)

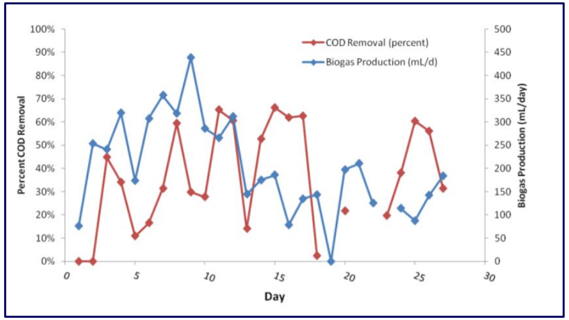
- granules process the COD to produce **biogas** (Methane and Carbon Dioxide)

- biogas is captured by Gas-Liquid-Solid (GLS) separator

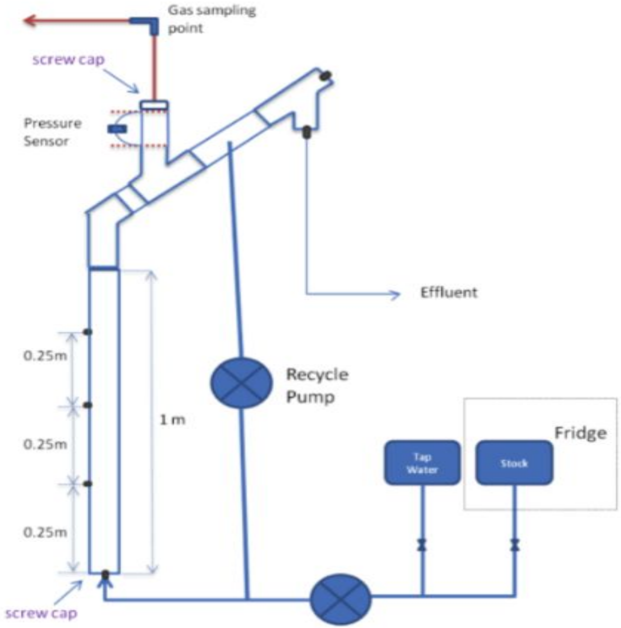


Previous Work and Challenges

- Summer 2013 Goals and Challenges
  - Remove COD, turbidity, and pathogens
  - Energy neutral reactor through collection of biogas
  - Challenges: Poor treatment efficacy
    - Biomass washout, granular disintegration, scaling

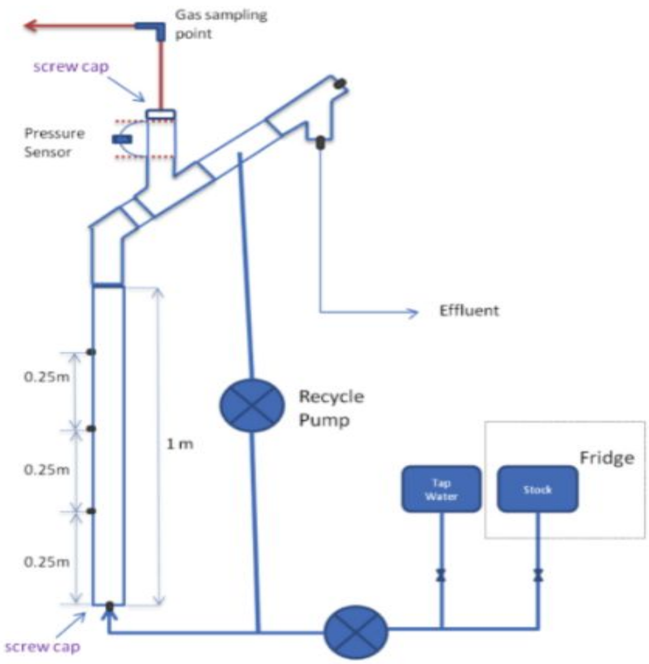


Summer 2013 testing



Previous Work and Challenges

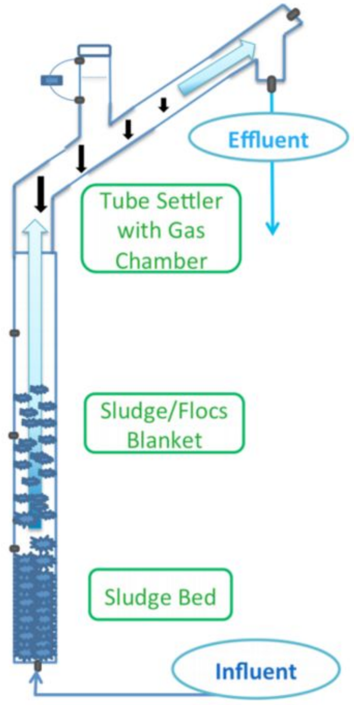
- Fall 2013 Goals and Challenges
  - New gas chamber sealing method
  - Models for particle fluidization and settling
  - Dissolved methane tests
  - Characterization of granules
    - Confocal microscopy and chemical staining
  - Challenges: inability to collect significant data for gas production
    - Leaks, lengthy startup time



Fall 2013 Gas sampling method

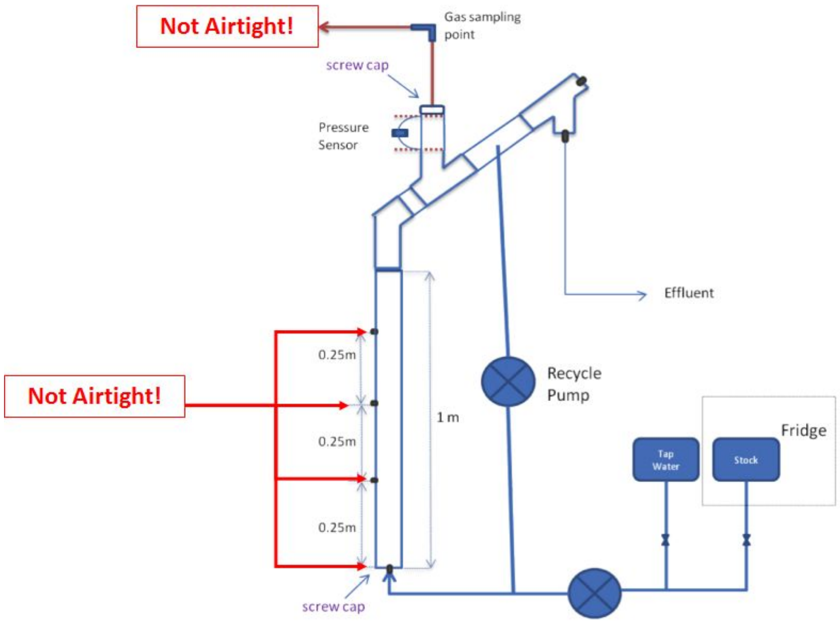
Previous Work and Challenges

- Spring 2014 Goals and Challenges
  - Gas chromatography to monitor methane production: Bag test
  - Fixing leaks: Teflon tape, parafilm and epoxy
  - Operational changes:
    - Heating
    - Double strength of wastewater
    - Double hydraulic retention time (HRT)
    - Reduce pump flow rate to half
  - Challenges: inconsistencies between theoretical and experimental gas production, inconsistent COD feed concentration delivery, and vessel leakage



Semester Goals

- Determine effectiveness of current design with respect to:
  - treating influent COD
  - producing biogas
  - minimizing biogas losses due to leaks and dissolved methane



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Methods

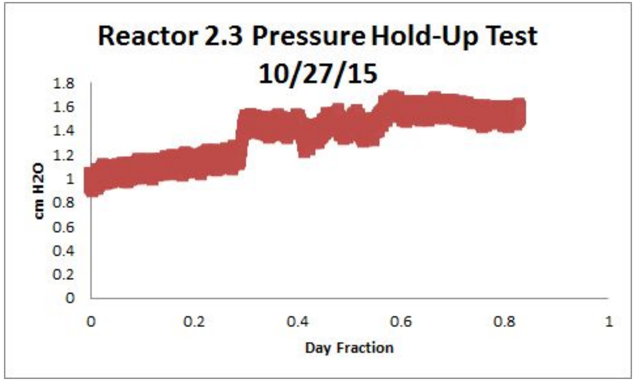
1. Testing Air Loss

 -Soap Test: High pressure over short duration

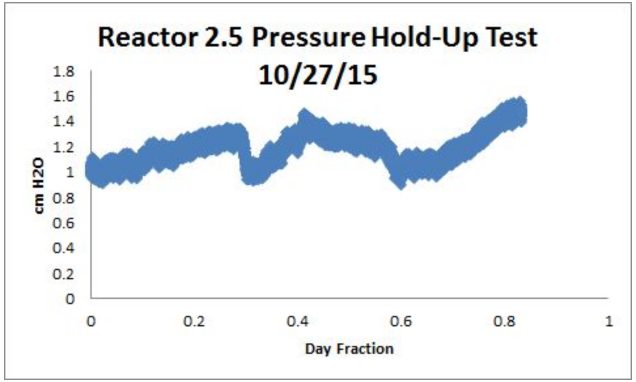
 -Pressure test: operational pressure over long duration

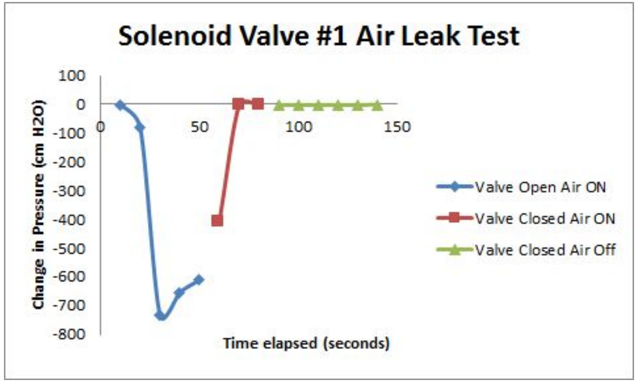
2. Valve Tests

Air Loss and Valve Test Results



Water Level Change (cm/d)	0.75
ID of PVC 40 (cm)	4.09
Area of PVC (cm^2)	13.13
Volume Lost (mL/d)	9.85
Biogas Production (mL/d)	250
Biogas Lost (%)	3.94



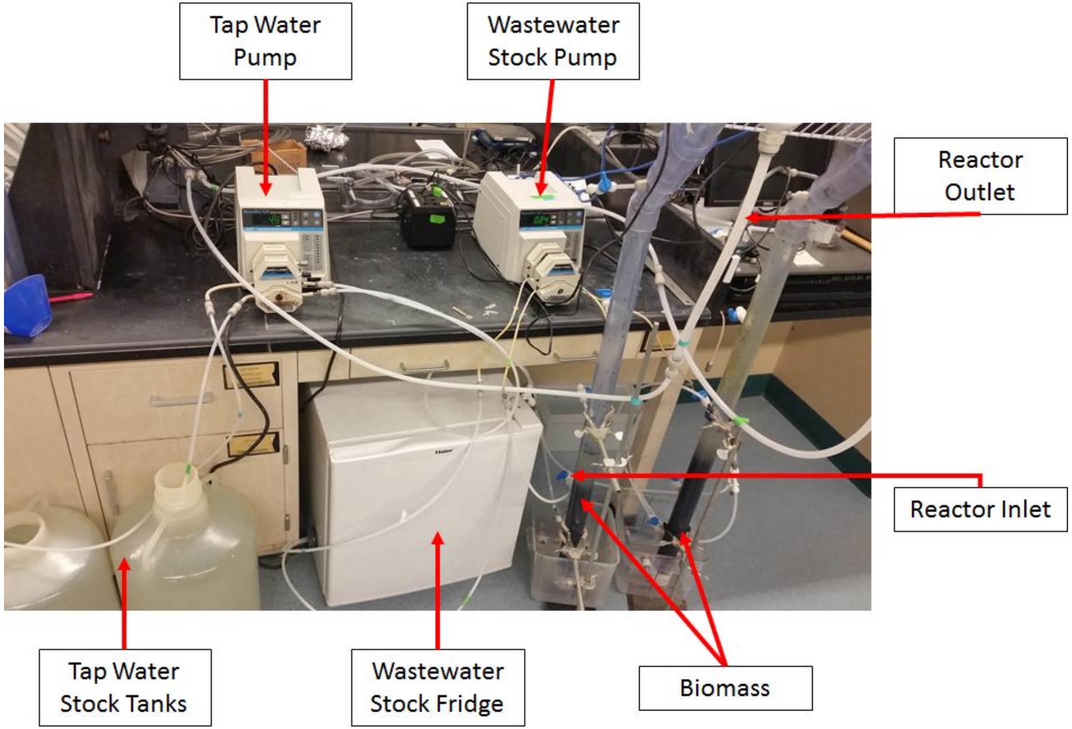


Methods

3. Inoculation

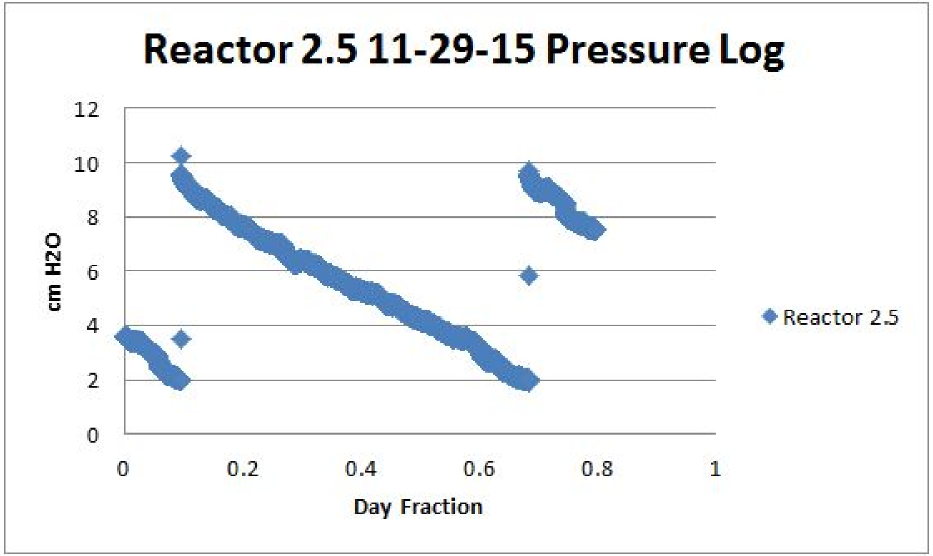
    a. Tubing, Pumps, Stock, Tanks, Fridge

4. Biogas Production Measurement



Biogas Production Results

Biogas Production Measurement



1st event		
low P value	2.14	cm H2O
high P value	10.26	cm H2O
Difference	8.12	cm H2O
Area PVC	13.14	cm^2
Volume offgas	**106.69**	**mL**

2nd event		
low P value	4.02	cm H2O
high P value	12.50	cm H2O
Difference	8.48	cm H2O
Area PVC	13.14	cm^2
Volume offgas	**111.40**	**mL**

Total Gas Production 11-29-15	
218.1	**mL**

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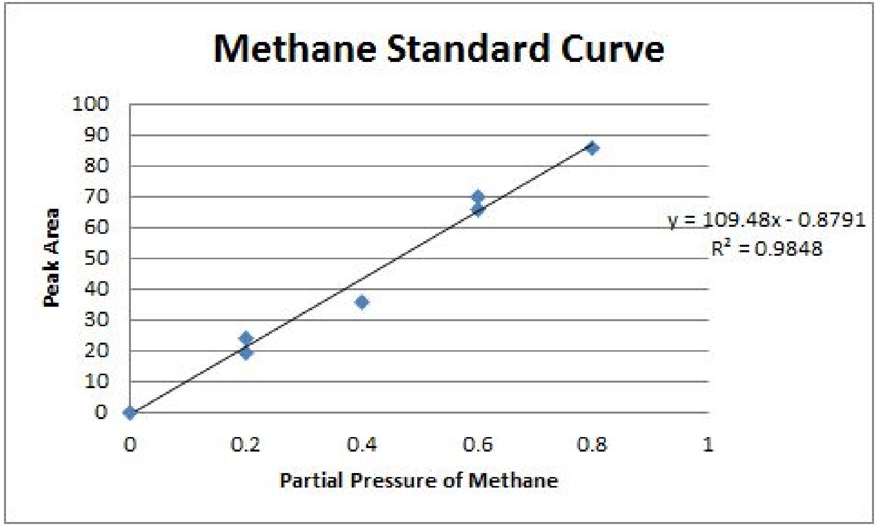
Methods

5. COD analysis

6. Gas Chromatography

COD and GC Results

Date	Total Gas Production (mL)	Volume Fraction Biogas	Volume Methane Produced (mL)	Influent COD (mg/L)	Effluent COD (mg/L)	% COD Treated	% Theoretical Methane Production
11/29/2015	218.1	~65	147.5	789	129	84%	59%
11/30/2015	149.4	~65	97.1	632	72.9	88%	48%
12/1/2015	142.9	65.5	93.3	2360	109	95%	12%



COD and GC Results

	Influent COD (mg/L)	Effluent COD (mg/L)	% COD Treated
Reactor 2.5			
29-Nov	789	129	84%
30-Nov	632	72.9	88%
1-Dec	2360	109	95%
Reactor 2.3			
29-Nov	333	57.8	83%
30-Nov	128	43.7	66%
1-Dec	305	-0.549	100%

Reactor 2.5

Date	Total Gas Production (mL)	Volume Fraction Biogas	Volume Methane Produced (mL)	Influent COD (mg/L)	Effluent COD (mg/L)	% COD Treated	% Theoretical Methane Production
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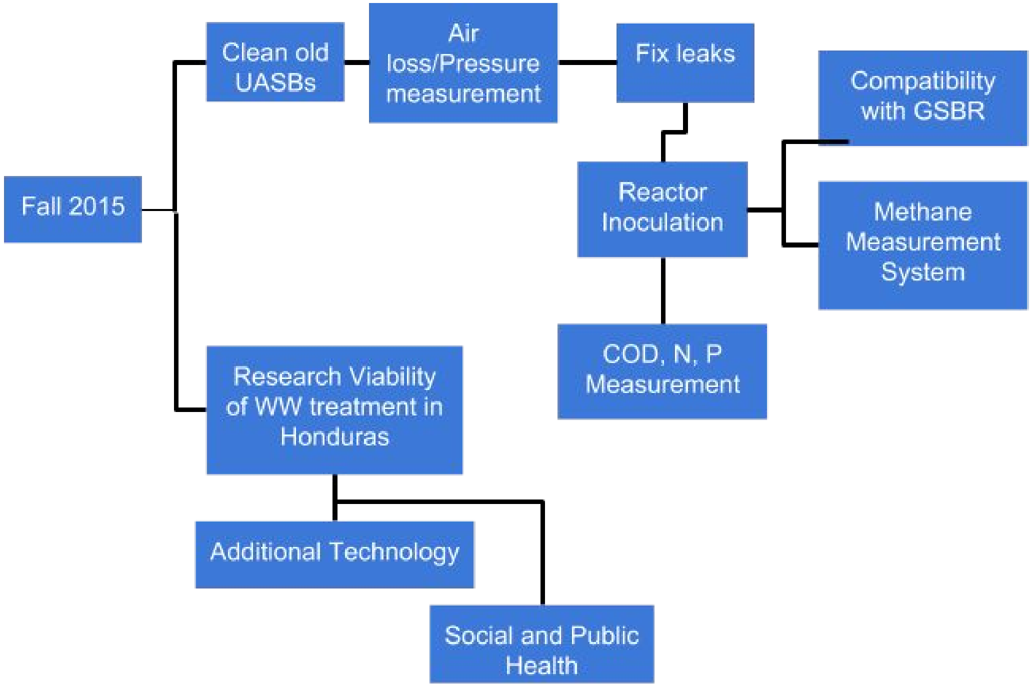
Conclusions

	Fall 2013 Rctr 2.4	Fall 2013 Rctr 2.6	Spring 2014 Rctr 2.4	Fall 2015 Rctr 2.5
Methane Prod. (mL/day)	116.8	139.5	227.5	141.8

- Leaks quantified at ~4% theoretical biogas/day production
- Instrumentation setup and reactors inoculated
- Biogas production monitored via pressure sensor offgassing
- COD removal quantified ~85%
- Methane production ranged from 12-59% theoretical value

Challenges/Future Work



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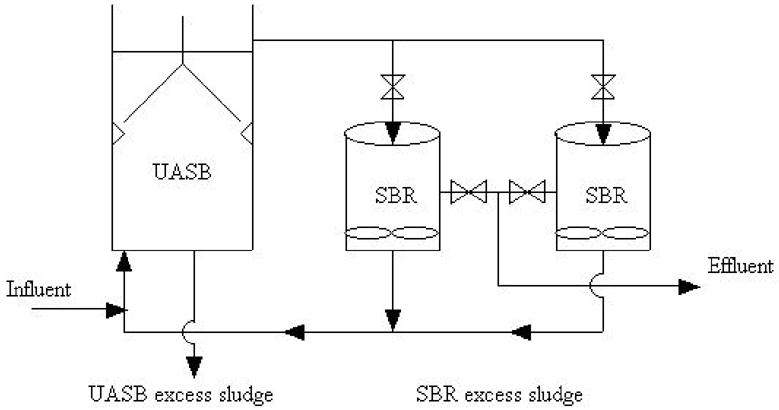
Future Work

- Modify reactor design
  - Air tightness
- Wastewater stock delivery
- Process Controller modifications

Future Work

- UASB-GSBR coupling
- UASB treatment of Nitrogen, phosphorus and, possibly, fecal indicator bacteria (harmless E.coli)
- Oxygen stress tests



Questions/Comments?

Thank you!

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